Interim Report

Elasticities of Electricity Demand in India

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1. Introduction

In India, the power generating capacity, owned and operated by utilities, has grown at a rate of over 10% compounded annually since 1950. Of the 81164 MW commissioned until 31 March 1995, more than 60% had been added since 1980.[1]

The shares of hydro power and thermal power have changed substantially since the early 1970s. The share of hydro capacity declined from 43.4% in 1970/71 to 39% in 1980/81; by 1994/95 it had further reduced to 25.5%. It is difficult to strike an optimal balance between hydro and thermal power, as it may depend upon the system load curve, performance of various types of plants, etc. Given the Indian energy situation characterized by shortages in peaking, it is believed that efforts must be made to increase the share of hydro capacity in the future. The share must be increased to at least 34% over the next 15 years.[2] Perhaps, one of the most important reasons for the decline in the share of hydro capacity is that its gestation period is considerably longer than that of thermal capacity.

1.1 Electricity consumption and sectoral composition

Though the per capita consumption of electricity in India is low (289 kWh in 1994/95), the demand for electricity has been increasing at a fast rate outstripping its availability. Electricity consumption grew at an annual compound rate of 10% during 1950-1993/94. The pattern of consumption has undergone a significant structural change during the past four decades, with an increase in total electricity consumption in the agriculture and domestic sectors. The rural electrification programme launched by the government in the mid-sixties resulted in large-scale energization of pumpsets. This, along with subsidized electricity, has led to a rapid increase in electricity consumption in the agriculture sector. Consequently, the total electricity consumption of the agriculture sector has increased at the fastest rate (at 15.3% per annum) during the period 1950/51 to 1993/94. In states such as Punjab, Haryana, Uttar Pradesh, and Andhra Pradesh, nearly 35-40% of the total electricity consumption is used for irrigation purposes.

Electricity consumption by the domestic sector increased at a compound growth rate of about 10% a year during the last four years, which nearly doubled its share in total electricity consumption. Increasing urbanization and increased use of domestic electric appliances are possible reasons for such a trend.

The industrial sector, though still accounting for the highest share in total electricity consumption, registered a decline in its share in total consumption, from 70.6% in 1965/66 to

40% in 1993/94. A large number of industries are increasingly relying on captive power because of increasing power shortages and poor quality of grid supply. As on 31 March 1992, the total captive installed capacity was about 10000 MW.

The commercial sector, consisting of shops, offices, institutions, hotels, etc., continues to account for 5-6% of the total electricity sales. Electricity consumption in railways, though accounting for only 2.3% of the total electricity consumption, increased from 372 million kWh in 1970/71 to 6931 million kWh in 1992/93, an annual growth rate of 15%.

The financial performance of State Electricity Boards (SEBs) has deteriorated significantly over the years. The rate of return of all the SEBs declined from -10.5% in 1985/86 to -14.2% in 1991/92 (as against the statutory minimum rate of 3% specified in the Electricity Supply Act). The SEBs incurred a net cumulative loss of Rs 41.2 billions, as on 31 March 1992. The poor financial condition of the SEBs poses formidable problems not only for their future development but also in meeting their day-to-day expenses.

The most important reason for the poor financial condition of the SEBs is their unremunerative tariff policy. The per unit average revenue realized by all the boards is less than their average cost of generation and supply. The gap has increased from 3.7 paisa/kWh in 1974/75 to 24.7 paisa/kWh. Moreover, agriculture and domestic sectors are heavily subsidized. Flat rates based on the horsepower of the pumpsets have, in many cases, resulted in the misuse of electricity and groundwater resources.

1.2 Economic growth and electricity consumption

Several studies relating to electricity consumption and economic activity are available.[3,4] In India, the growth in per capita electricity consumption has been faster than the rate of growth in per capita real GDP. Electricity consumption per capita in India increased from 32 kWh in 1960/61 to 289 kWh in 1994/95,[5] with a compound annual growth rate of 6.7% per annum, and GDP per capita (at 1980/81 prices) has increased from Rs 1449 to Rs 2777 during the same period, with a growth rate of 1.9% per annum.[6] Table 1 gives the growth of electricity consumption and GDP on a per capita basis for five yearly intervals, since 1960/61. There has been an increase in electrical energy intensity. The overall electrical energy intensity in the Indian economy in terms of kWh/Rs GDP (at constant price) has shown an upward trend from about 0.02 in 1960/61, 0.05 in 1970/71, 0.07 in 1980/81, 0.09 in 1990/91 to around 0.10 in 1994/95. This has been due to:

- lower price of electricity mainly in the agriculture and domestic sectors as compared to the real cost of supply of electricity;

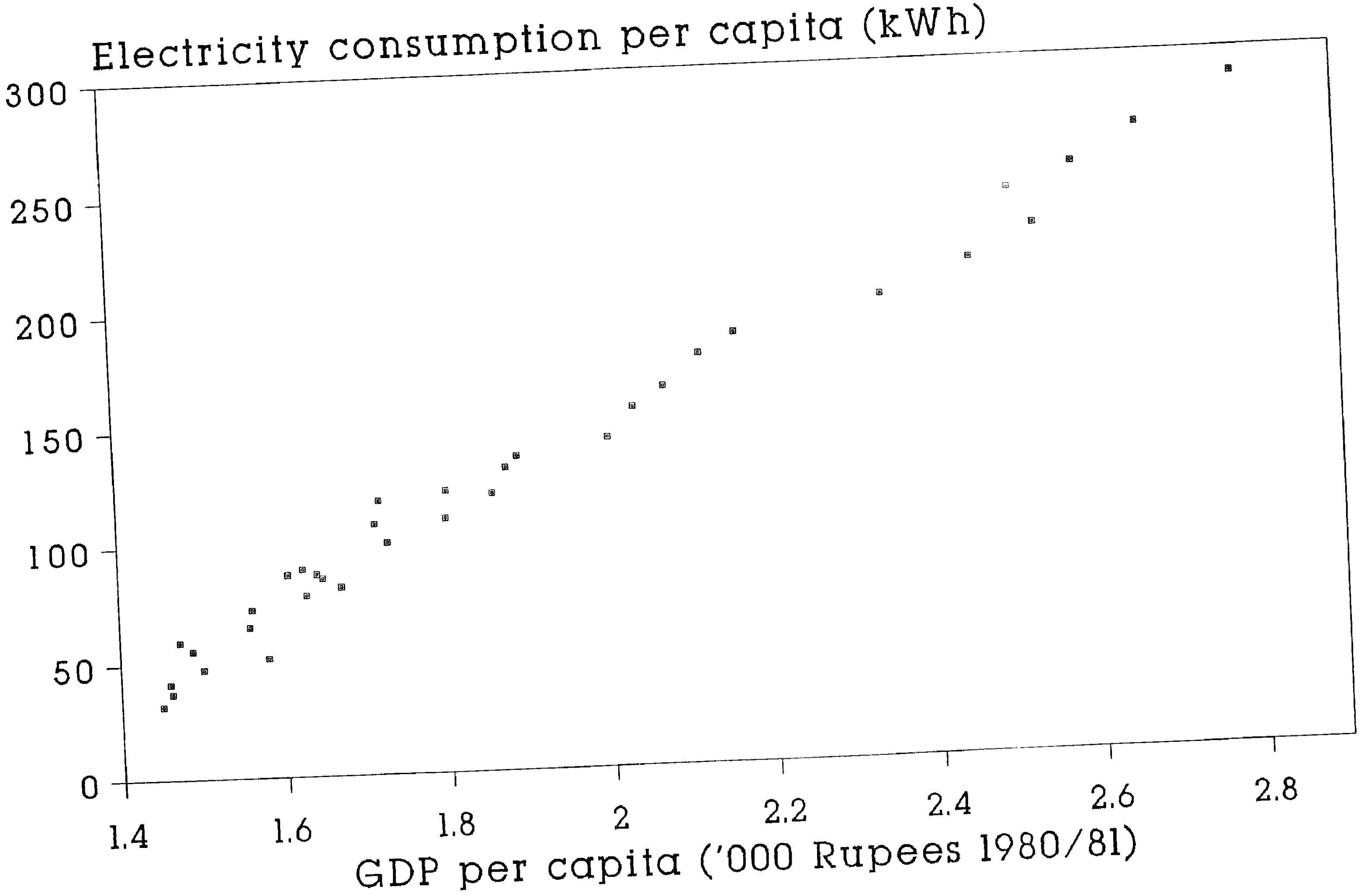
- increased personal incomes and penetration of consumer durable;
- rapid pace of urbanisation;
- level of activity in individual electricity using sectors;
- incresing penetration of irrigation pumpsets due to mechanization of agriculture;
- changes in the composition of GDP;
- changes in technology.

Table 1. Electricity consumption and GDP per capita in India

Year	**Electricity consumption**[*] *million kWh*	**Population**[*] *million*	**Elect. per capita** *kWh*	**GDP per capita**[**] *Rupees 1980/81*
1960/61	13841	434	32	1449
1965/66	26735	485	55	1487
1970/71	43724	541	81	1671
1975/76	60246	607	99	1729
1980/81	82367	679	121	1803
1985/86	122999	755	163	2074
1990/91	190357	839	227	2530
1994/95	260842	904	289	2777
Compound annual growth rate (%)				
1960/61-65/66	14.1	2.2	11.6	0.5
1965/66-70/71	10.3	2.2	8.0	2.4
1970/71-75/76	6.6	2.3	4.2	0.7
1975/76-80/81	6.5	2.3	4.1	0.8
1980/81-85/86	8.4	2.1	6.1	2.8
1985/86-90/91	9.1	2.1	6.8	4.1
1990/91-94/95	8.2	1.9	6.2	2.4

Source: from endnotes no. [*]6 & [**]5.

Fig 1. Electricity-GDP relationship
1960/61 - 1994/95



On analysing the last 35 years annual data (1960/61 to 1994/95) on per capita electicity consumption and per capita GDP at constant (1980/81 price), a strong degree of linear relationship is established (Figure 1). The correlation coefficient is 0.98 indicating that higher level of economic growth implies a higher electricity consumption.

1.3 Electricity demand planning

Electricity plays a significant and decisive role in economic development of the country. There is a strong correlation between per capita income and per capita electricity consumtion. The electricity consumption is basically characterized as a function of gross domestic product (GDP), penetration of consumer durable, level of urbanization, level of industrial output and tariff structure of electricity in different consumer categories.

One of the most commonly used methods of characterizing, planning, and forecasting electricity demand is either to calculate the energy consumption-GDP ratios (simply the energy-income ratios), or to estimate the income and/or price elasticities of electricity demand (in short the elasticities).

The elasticity estimates have been used by numerous researchers worldwide to understand demand behaviour and also to undertake other activities like forecasting, demand management and policy analysis. These elasticity estimates have particular relevance for designing pricing policies because properly set electricity tariff that reflect their true costs minimize behavioural distortions and uneconomic fuel substitutions. If producers and consumers of electricity receive incorrect price signals, resources are misallocated with adverse effects on economic growth and development.

Given this background, the Tata Energy Research Institute (TERI), New Delhi, has been entrusted with a special study in the power sector, by the Environmental Resources Management (ERM), London, to analyse the elasticities of power demand at the national level. The aim is to use the elasticity estimates for demand forecasting of the power sector in the next 10-15 years.

2. Objective

The objective of the study is to -

- undertake a review of existing literature (both at the national as well as at the international level) containing the relationships between energy and in particular, electricity demand and the variables influencing the demand;

- study factors influencing electricity demand through regression analysis;
- estimate price and income elasticities of electricity demand at the national level;
- analyze elasticity estimates separately for different electricity consumer categories, viz., domestic, commercial, industrial (low & medium voltages together and high voltages) and agriculture;
- analyze elasticities of other parameters which influences power demand.

3. Literature Review

3.1 Developed countries

Numerous studies are available on elasticities of different variables influencing energy and electricity demand in developed economies. The following section gives an overview of the literature available on the subject.

3.1.1 Energy demand elasticities

A paper on the determination of total energy demand in Québec, Canada, is prepared by *Arsenault, Bernard, Carr and Laplante (1995)*[7] using the data for the period between 1962 and 1990. A two-stage model is defined to give total energy demand by sector at two levels. At the first stage, the share of various energy sources are taken as a function of the corresponding lagged share of energy sources and their relative prices. While at the second stage, total demand of energy is measured as a function of lagged consumption, real energy price, real income and heating degree days which is a measure of temperature. A logarithmic-linear form of function is used to determine the demand in residential, commercial & industrial sectors. The model is termed as the integrated two-levels model by the authors. The sector-wise short and long-run price and income elasticities are estimated with final sets of results given in Table 2.

The price elasticities comes out to be inelastic (less than one) for all the sectors except for street lighting in the long-run (where it is elastic), while income elasticities is also less than one for all the sectors except for industrial sector in the long-run.

Bentzen and Engsted (1993)[8] estimated short- and long-run elasticities of energy demand for Denmark using the data between the period 1948 and 1990. The energy demand

which is non-stationary variable is assumed to be a function of real GDP, real price of energy and temperature variable measuring the heating degree days. A linear double log form with lagged variables to incorporate the dynamic aspects is used to estimate elasticities. A statistical assumption made here is that the variables are stationary stochastic processes i.e. the variables have constant unconditional means and variables. The authors have estimated long-run income elasticity to be 1.213 and long-run price elasticity to be -0.465. Their analysis show that for Denmark the aggregate energy demand is income elastic and price inelastic in the long-run.

Borges and Pereira (1992)[9] used a KLEM model, which is defined by the variables - capital, labor, energy and material to constitute the output, to study the demand for each individual energy inputs in Portuguese manufacturing industries. The demand is assumed to be a function of relative energy prices, keeping total energy input constant.

Table 2. Short and long-run price and income elasticities for Que'bec

Sector	Price elasticity	Income elasticity
Residential		
Short-run	-0.28	0.14
Long-run	-0.68	0.35
Commercial		
Short-run	-0.33	0.38
Long-run	-0.59	0.69
Industrial		
Short-run	-0.16	0.60
Long-run	-0.35	1.33
Street Lighting		
Short-run	-0.15	0.03
Long-run	-1.21	0.27

Using the KLEM model, composite price of energy is defined as a function of prices of electricity, fuel and coal in the logarithmic form. The price elasticity for Portugal is estimated as -1.26, which is higher as compared to USA (-0.47) and Canada (-0.49). The paper reveals that in Portugal, the energy demand in manufacturing industry responds significantly to the price changes, given there are important substitution possibilities among the energy forms and between energy and other means of production.

The demand elasticities for seven major energy consuming nations including USA, Canada, Germany, France, UK, Italy and Japan are evaluated by *Prosser (1985)*[10]. The author used the data on aggregate energy demand, aggregate GDP and average price for these nations. Of the four models considered amongst static model with a linear relationship and no lagged effects, static model with lag of maximum 5 years, model called Almon scheme with weights of the lagged coefficients represented by a polynomial and lastly Koyck assumption where the lagged coefficients follow a declining geometric sequence. The last model is accepted as the best method by the author. The income and price elasticities are calculated for the period ranging from 1960 to 1982 with data sorted in 12 year sequences. This gives different elasticities for years before and after 1971. According to the author, pre-1971 elasticity values are unreliable, while post-1971 data gives income and price elasticities as 1.02 and -0.37 respectively.

3.1.2 Electricity demand elasticities

Filippini (1995)[11] has used the time-of-use tariffs structure to determine the electricity demand. The author has assumed that the consumer decides his expenditures in two stages. At the first stage, the consumer allocates his total expenditure between various commodities including electricity, while at the second stage the electricity demand is determined using the electricity prices during the peak, off-peak periods and the total expenditure on electricity as determined in the first stage. This model is termed as the AIDS (Almost Ideal Demand System) model. The data on electricity consumption for the period 1987-1990 on 220 households living in 19 Swiss cities is used in the analysis. The price elasticities estimated in peak and off-peak period range between -1.29 to -1.50 and -2.36 to -2.42 respectively.

Brand (1990)[12] on the impacts of the structures of electricity and gas tariffs at the national use of energy in Germany concluded that for electricity, time-of-use tariff structure is advisable because there is a high potential for load shifting even in the households.

Analysis of short- and long- run electricity demand is done by *Flaig (1990)*[13] for Germany using a theoretical model. The electricity demand considered as a function of its

own price, price of its complement and substitute and price of the produced commodity. The partial least squares (PLS) which assume that the theoretically defined variables like capital stock, electricity demand, etc. are only indicators with certain mathematical errors. In fact, PLS is an iterative sequence of ordinary least square (OLS) technique. The aggregate annual data for 1964-83 for German households is used in the estimation of short and long-run demand elasticities.

Peck and Weyant (1985)[14] in their paper have discussed the model of electricity demand in the USA by consumer categories (viz., domestic, commercial and industrial). The model is defined as a function of behavior of real prices (i.e. inflation-adjusted) of electricity, the prices of substitutes for electricity (e.g. oil and natural gas) and the behavior of national income, industrial output etc. The authors have analyzed the past trends in electricity demand and ha projected future demand using a growth rate method. The data on sectoral electricity demands for the period between 1963 and 1982 have been used. Estimates of own-price elasticities in the residential sector range from -0.7 to -0.10, while that of cross price elasticities range from 0.075 to 0.225. The estimates for income elasticities range from 0.775 to 1.325.

For the residential demand of electricity in USA, a national household sample survey data is used by *Garbacz (1983).*[15] The residential demand function is determined from the primary demand for the services of appliances and other electrical devices used in the households. The author assumes that in the short-run changes in income and price affect the electricity consumption. While in the long-run households have the chance to get adjusted to the appliances and the residence size which is determined with the change in income. The model in terms of electricity demand, price and appliance stock is estimated using the ordinary least square (OLS) technique. The model is in the log-linear form. This model with electricity demand, its price and appliance stock index with current national household data-set are used to develop a partial and total elasticity estimates for USA. Partial elasticities for income and price are calculated as 0.102 and -0.193 respectively, while the total elasticities of income and price for the residential demand are estimated as 0.410 and -1.403 respectively.

Smith (1980)[16] estimates price elasticity of electricity demand in the residential sector. The author suggested that demand elasticity estimates based on state-wide aggregates are less relevant for any individual utility. To make the demand estimates, 27 investor-based US utilities over the period 1957-72 have been considered by the author. Residential electricity demand is taken as a function of price, income, prices of substitutes, measures of use of electric appliances and a variety of environmental variables, like heating degree days and

temperature. The log-linear demand models are estimated which gives the estimates for the price and income elasticities for these utilities -- ranging from -0.07 to -1.56 and 0.59 to 1.76 respectively.

3.2 Developing Countries

Like the developed economies, a number of studies are also available on the elasticities of energy and electricity demand in developing countries. Among the developing countries, some selected studies have been reviewed and presented in the following sections.

3.2.1 Energy demand elasticities

A recent paper by *Chan and Lee (1996)*[17] estimates energy demand forecast for China for the period between 1994-2000. The model is defined with the variables like energy consumption, national income, price of energy and an indicator of structural variation which is the share of heavy industry in the national income in this case. The model is stated in the vector form in terms of lagged time series data. The model is referred as Vector Error Correction (VEC) model by the authors. The projections of energy demand is expressed in terms of coal equivalent of energy till 2000.

A study on the effectiveness of time-of-use (TOU) rates in Korea has been done *Kim (1995)*[18]. The author established a pattern of electricity consumption under TOU rates, which are applied to various customers at three different levels i.e. peak, shoulder and off-peak rates. The data for the period between February 1987 to December 1992 is used to analyse this. A logarithmic function for industry production called KLEM model with electric energy is divided into three parts according to the time of use. The estimates of own-price elasticity under various rate schedules for day, evening and night period vary between -0.10 and -0.39, -0.23 and -0.39, & -0.39, & -0.19 and 0.11376 respectively showing that the elasticities vary from one customer to another. The cross-price elasticity estimates range from 0.37 to -0.022 implying that the electricity usage by TOU are more substitutive especially for day and evening periods.

The aggregate energy demand and the corresponding elasticities for the countries like India, Bangladesh and Pakistan are estimated by *Pourgerami and Von (1991)*.[19] The model used by them is a function of factors like income, price, consumption habits and population, which affect the energy demand at one stage, while the other factors like capital formation and agriculture output are also considered at the second level of estimations. Estimates on the

income and price elasticities based on two models are found to be different. The ranges for the price and income elasticities according to the factors defined at stage one varies from -0.34 to -1.33 and 0.27 to 1.04 respectively. When parameters like capital formation and agricultural output are included these price and income elasticities vary from -0.39 to -1.34 and 0.32 to 1.12 respectively.

Jones (1989)[20] analyses the impact of urbanization on energy use in economic development in fifty-nine developing countries using cross sectional data. The countries in the sample range from the more developed countries of Argentina and Brazil to Bangladesh, Haiti, and Sudan at the opposite end of the development spectrum. Aggregate energy use per capita and per dollar of GDP is regressed on per capita income (adjusted for purchasing power parity), the percent of GDP coming from industry, the percent of the population urbanised, arable population density, and several product-specific fuel prices. Holding constant per capita income, industrialization, population density, and fuel prices, the elasticity of energy consumption with respect to a one percent increase in urbanisation is between 0.35 and 0.48. The implication is that, although increasing per capita income and industrialisation are important sources of increases in energy consumption, urbanisation alone is also an important source of increased consumption and could be a major factor in world energy demand over the next generation.

Reister (1989)[21] in his paper links energy and GDP using the data on per capita GDP and per capita energy demand for 38 developing countries. He classified the countries into three group on the basis of the per capita GDP (the class boundaries are $0-$1000 for class A, $1000-$2000 for class B, and $3000-$4000 for class C). The model in log-linear relationship is estimated between per capita energy demand and per capita GDP. The estimates obtained for income elasticities decline from 1.90 in 1950 to 1.71 in 1980. The analysis is based on the purchasing power parity method.

Zilberfarb and Adams (1981)[22] looked at energy-GDP relationship for the developing countries. They established the relationship between energy consumption and GDP using time series data on per capita energy consumption and per capita GDP for the period between 1970 and 1976 and found the elasticity of energy consumption. The estimates of elasticities came out to be significantly higher than one (highly elastic) which is fairly stable during the time period.

Another study by *Ibrahim and Hurst (1990)*[23] on thirteen developing countries including Brazil, India, Korea, Morroco, Pakistan, Philippines, Taiwan and Thailand (oil-importing developing countries) and Algeria, Egypt, Indonesia, Mexico and Saudi Arabia (oil-exporting

developing countries) found a strong link between income and energy/oil demand for the period ranging from 1970 to the mid-1980s. The income and price elasticities for oil and energy using factors like the level and pattern of energy demands are estimated using the energy consumption function determined by the factors like real GDP, indices of energy pricing and other explanatory variables which determine oil consumption behavior.

In the same paper by *Ibrahim and Hurst (1990)*, the authors also refer to the work of *Williams and Laumas* for selective manufacturing sectors in India with pre-1973 data. Here, the analysis is done by estimating the time series demand equations in terms of energy consumption using log-log relationships, ordinary least square (OLS) fit and other regression techniques. For the oil-importing countries both annual aggregate energy consumption and aggregate oil consumption is regressed against real GDP, indices of energy prices, and other explanatory variables that determine oil consumption behavior, for the period 1970 to the mid-1980s. Real GDP is used as a data point along with total energy price index which is weighted average of the price of oil products, coal, natural gas and electricity, to determine the aggregate energy consumption where the log aggregate energy consumption is taken as a dependent variable and income as an independent variable. The income elasticity are estimated to be 1.56 in this paper. The analysis shows that the price elasticity of energy demand is low and most long-run changes in demand take place rapidly. On the other hand, the income elasticity for most of the countries is close to one. Indeed the income coefficient is substantially greater than one in several countries, indicating that this is the dominant variable in determining energy consumption in developing countries.

A paper by *Fiebig, Seale and Theil (1987)*[24] on the energy demand with the cross country analysis presents some figures on income and own-price elasticities of demand for energy consumption. In this paper a complete system of demand equations, with energy being just one of the commodities, is considered. This analysis gives the variation in income and prices for a sample of countries varying in affluence from India to USA with varying per capita real income and the corresponding share of energy in the complete demand system. This paper gives the income elasticity variation from 1.24 for USA to 1.64 for India with the estimates ranging between them for various other countries like Denmark, Netherlands, Japan, Mexico, Brazil, Korea, Srilanka and Pakistan as 1.25, 1.26, 1.27, 1.31, 1.35, 1.38, 1.51 and 1.55 respectively. The corresponding own price elasticities for USA and India are estimated as -0.66 and -0.87 respectively with the same countries as mentioned for income elasticities having values between this range. The own price elasticities for the same order of countries are -0.66, -0.67, -0.68, -0.69, -0.72, -0.73, -0.80 and -0.82 respectively.

It is observed that income elasticities are greater than unity for all countries, with developing countries having values closer to two than one, while the countries with very low income levels elastic own-price responses.

The estimates of energy and non-energy elasticities in selective Asian manufacturing sectors are calculated by *Siddayao, Khaled, Ranada and Saicheua (1987)*[25] with focus on food processing and textile industries. These industries are selected because they are important for the development of the developing countries. They estimated the elasticities using the logarithmic functional form. The assumption made in the analysis for each industry was that a positive, strictly increasing twice differentiable and strictly quasi-concave production function exists.The production function is defined in terms of four input services, capital(K), labor (L), energy(E), and raw materials(M) which combine to produce the industry output (Y). The assumptions made are that returns to scale are constant and the technical progress can be represented as disembodied and neutral with the time variable which represents the effects of technical change. The study is done for three countries i.e. Philippines, Thailand and Bangladesh and compared with Indian manufacturing industries (Tables 3 and 4). For India, the own-price elasticities in sugar, cotton, textile and iron & steel industries are considered. The partial elasticity of substitution, full elasticity of substitution and own-price elasticities of demand are derived in this paper from the parameter estimates of the logarithmic model with the inputs. The price elasticity of energy demand in specific developing countries are estimated.

Table 3. Own-price elasticities in India

Industries	E_{KK}	E_{LL}	E_{EE}	E_{MM}
Sugar	+0.22	-0.61	-0.04	-0.07
Cotton & textiles	-0.20 to -0.14	-0.13 to -0.33	-0.66 to -0.46	-0.12 to +0.01
Iron & steel	-0.01 to -0.001	-0.01 to -0.001	-0.03 to -0.001	-0.01 to -0.11

able 4. Elasticity of demand for other Asian countries

Country	E_{KK}	E_{LL}	E_{EE}
Bangladesh (1970-80)	-1.99	-0.48	-0.31
Philippines (1970-77)	+0.20	-0.14	-1.25
Thailand (1974-77)	-0.56	-1.13	-1.71

High estimates of elasticities in cotton and textile industries show that there is a possibility for energy demand response to changing energy prices. The study has varied results depending on the various industries studied and also across various countries. The elasticity for the Philippine industries came out to be lower than those for Thailand for all industrial groups.

A paper on the residential sector of Hong Kong was written by *Lam (1996)*.[26] The paper made observations on the energy-consumption data on 200 households in 5 different classes of residential units. It is observed that the ratio of consumption among different classes is proportional to the ratio of floor areas. The data for the period between 1979-93, suggested that estimations for the electricity consumptions are better estimated from the different residential sub-sectors. The author has suggested that such analysis is useful for most of the developing countries.

3.2.2 Electricity demand elasticities

Huang (1993)[27] considered per capita total electricity consumption to be a function of per capita GDP and per capita total electricity consumption in the previous years with the lagged values. The data for the period between 1950-1980 is used and simple regression analysis is done for the data available on the defined variables. The obtained estimates of income elasticities range from 2.33 to 2.72 for the period 1950-1980,
which when broken into two periods give estimates ranging from 3.52 to 3.72 for the period 1950-1970 and from 1.50 to 1.56 for the period 1970-1980.

Another study on energy demand in manufacturing industries in India was undertaken by *Roy (1992)*[28]. The analysis is based on a logarithmic function using database for the period 1960 to 1971. The extension of the findings are used to determine the elasticities for each sector. The study observed that the dependence on oil in industries can be reduced by influencing the demand responsiveness of the industrial consumers through price mechanism.

The responses of the individual industries vary with the relative prices. A one percent change in oil price is expected to induce 1.22 percent change in oil demand, (in the reverse direction), 0.25 percent change in electricity demand and 0.19 percent change in coal demand (both in the same direction). However, at disaggregate level, there are certain deviations from this behavior. In few industries the highest responsiveness of oil demand is observed while for other industries the high response for coal demand or electricity demand is observed.

The own and cross price elasticities for some major industries like mining, manufacturing, electric utility, industrial are compared with other studies. For instance, in India the own-price elasticities in mining & manufacturing sectors are estimated for coal, oil, electricity as -0.15, -0.09 and -0.14 respectively by Uri. The cross price elasticities between coal, electricity and oil range between 0.10 to 0.16. In case of manufacturing sector in India the estimates for own-price elasticities of coal, oil and electricity by Apte and Murty are estimated in the range of -0.12 to -1.90, -0.29 to -3.26 and -0.03 to -2.30 respectively.

It is observed by the authors that in estimating the energy/electricity demand and their elasticities in the developing countries, the most common problem which they face is that of unavailability of data. Reliable aggregate energy consumption data is not available before 1970, and the sectoral data that exist are based on the unjustified assumptions and unallocated consumption. Also the data on energy prices are particularly difficult to find.

It is also felt by them that literature on the demand for energy is generally concerned with the situation in the developed countries. They felt that in India, in case of electricity it is difficult to analyze the impact of prices on the consumption at the country level for various consumer categories owing to the fact that tariffs vary significantly from one state to another and the tariff revision in any state are guided more by their state governments socio-political objectives rather than financial or efficiency objectives. The factors such as high growth rate of electricity consumption in agriculture and domestic sectors and the improvements in energy efficiency in the industrial sector are set responsible for the decline in the share of electricity consumption in the industrial sector by the authors.

A paper on the relationship between the electricity consumption and economic growth in Jamaica by *Ramcharran (1990)*[29] has analysed data for the period 1970 to 1986 using a double log linear model. The aggregate electricity demand is slightly income elastic with demand having significant effect on the economic growth. Of the aggregate demand, the residential demand determined by real income is income elastic, commercial and industrial demand determined by price is price inelastic, and the rate of adjustment to the higher price of elasticity by all the three categories of consumers is slow. For the residential sector, the

short- and long-run income elasticities are estimated to be 1.21 and 4.172 respectively, while the corresponding price elasticities are not significant. The short- and long-run price elasticities ranges from -0.257 to -0.19 and -0.43 to -0.52 respectively, while the corresponding income elasticities are not significant.

A study by *Sarkar and Kadekodi (1988)*[30] on energy pricing in India computes the effect of increased energy price on demand by specifying the extent and nature of inter-fuel substitution possible in the various consuming sectors. For analyzing the relevant issues associated with the energy price changes, broadly three alternative pricing regimes are considered. As the prices of petroleum, coal and electricity in India are set by government and do not adjust to the cost automatically, energy prices are assumed to be exogenous policy variables and the corresponding unit profit are determined as endogenous variables. For the non-agricultural sectors barring railways pricing follow mark-up pricing principle and this regime is referred to as 'energy prices administered' or 'EPADM' regime. In an alternate regime called the 'energy prices determined from mark-up pricing' or EPMARK regime prices of all non-agricultural sectors including energy are determined by applying a mark-up rate on the prime cost. In a third regime known as 'individual energy price administered' or 'IEADM' regime, the price of one fuel is considered as exogenous and all other fuel prices as endogenous. This regime is a mix of 'EPADM' and 'EPMARK' regimes and is used to study the impact of changes in one of the energy prices on all the sectors of the economy. All the regimes are analyzed under two broad assumptions 'with substitution' case and 'no substitution' case among the fuels.

The elasticities of substitution between the energy types for sectors like basic and other manufacturing industries, electricity and railways is estimated using econometric techniques on the basis of time-series of ratio of prices of two energy inputs and the corresponding income flows. These elasticities of substitution are studied with respect to energy price increases which determine the energy demand and other macro economic indicators through elasticities of substitution.

The result of the energy price increase is observed to be stagflationary i.e. real GDP decreases as price increases. These effects are more pronounced for price increase in petroleum followed by electricity and coal. The effects of energy price increases on income distribution is only marginal. The effects of energy price changes on the economy are modest because of relatively low energy intensity of Indian industrial system and fuel consumption. The findings show that, if industry is considered at an aggregate level the energy cost is only

a small fraction of the total cost while if industry is considered at a disaggregated level then energy costs become quite significant.

Glakpe and Fazzolare (1985)[31] estimate electricity demand for West Africa. The authors assume that each year's consumption is greater by a certain percentage to the previous year's consumption. The historical data is used to develop a mathematical model based on the electricity use and population growth. The total demand in the residential sector(kWh/year) of West African countries is defined as a function of average real price of electricity, total real disposable income of all households, and the number of households with access to electricity. These parameters expressed as per capita are used to fit the linear function which determine the electricity demand.

In the industrial sector the income elasticities show a direct correlation between electricity consumption and the output of the economy. The forecasts for electricity consumption in industrial and commercial sector are made considering it to be a function of the parameters like electricity consumption in the industrial/ commercial sector (in kWh/yr), real average price for electricity in these sectors, sectoral employment and sectoral real output. Regression analysis assuming a linear relationship between the variables is carried out. The price elasticities of energy demand by sectors and subsectors are calculated. From the energy demand equations important policy parameters like income and price elasticities which do not differ appreciably from *Yao's (1980)*[32] estimates are found to be -0.200 and -0.404 for the short and long run respectively. In this paper, price elasticities in the residential sector range from -0.310 for Nigeria to -1.240 for the Republic of Niger. The price elasticity for Ghana estimated to be insignificant because of abundant low-cost electricity from hydroelectric sources in Ghana and Nigeria, while on the other hand electricity prices are kept high in other countries because of their reliance on thermal power and its associated fuel costs and heavy consumption of electricity by the consumers. Ghana had however the lowest price elasticity in the industrial and commercial sector.

In the residential sector the price elasticities estimated are -0.195 and -1.240 for Ghana and Niger respectively, while the income elasticities are estimated as 0.279 for Ivory Coast and 1.236 for Niger. In the industrial and commercial sectors, the price elasticity is estimated at -0.459 for Niger and -0.850 for Burkina Faso, while income elasticities are estimated as 0.336 for Togo and 4.882 for Burkina Faso.

4. Framework for Analysis and Database

Time series data of electricity demand/consumption at the national level will be regressed with the factors influencing the demand function. The regression analysis would examine how incomes and prices, and also several structural characteristics of the country -- industrial structure, the extent of urbanization -- would influence the electricity demand in India.

4.1 Concept of elasticities

Demand elasticities refer to measures of the responsiveness of quantity demanded to changes in the determinants of demand. For instance, to understand how electricity demand gets influenced by the changing income levels can be determined by the income elasticity method. Income elasticity is defined as the percentage change in electricity demanded, as a result of the given percentage change in the income level, assuming that all other factors affecting electricity demand remain constant. Similarly, in the case of pricing structure influencing electricity demand, own-price electricity is the percentage change in electricity demanded resulting from a given percentage change in price of the electricity, assuming that all other factors affecting demand remain constant. Elasticities with respect to other prices (termed as cross-elasticities) are similarly defined. Own price elasticities should be negative, while the cross price elasticities should be positive for substitutes and negative for complementary commodities.[33]

4.1.1 Income elasticities of electricity demand

One of the important challenges to energy economists has been to find an approach to the determination of elasticities that is truely scientific. The present sudy is focussed on finding out the relationship between electricity consumption and economic growth (GDP) in India.

To estimate the income elasticities of electricity demand,[1] the study proposes to analyze time series demand equations using a double logarithmic linear relationships and ordinary least square (OLS) regression technique.[34] The following two equations will be used:

$$\ln E_t = a + b \ln Y_t \qquad (1)$$

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[1] Electricity demand will be equal to the total of electricity sold (to various consumer categories) and the shortages estimated by the State Electricity Boards.

$$\ln E_t = a + b \ln Y_t + c \ln E_{t-1} \qquad (2)$$

where E_t, Y_t are respectively per capita total electricity consumption and per capita GDP in year t. Subscript t-1 represents one-year lagged value and a,b,c are parameters of regression equations and can be estimated using the ordinary least squares fit. The estimated parameter b is the income elasticity in equation (1), but in equation (2) income elasticity should be estimated by computing b/(1-c).

Electricity demand data on per capita basis has been compiled for the last 20 years from 1975 to 1995 using the Central Electricity Authority documents.[35] The corresponding data for GDP at factor cost (at 1980-81 prices) has also been compiled from the latest Economic Survey and the National Accounts Statistics.[36]

4.1.2 Elasticities of electricity consumption

The major consumer categories in the electricity sector are domestic, commercial, industrial (low and medium voltages together and high voltages), agriculture (mainly for irrigation). Other consumers like public lighting, public water works, traction (railways) and miscellaneous categories constitute a very small proportion of electricity consumers. For instance, in 1993/94, of the total 238109 gWh (giga watt hour) of electricity sold to various consumers in India, share of domestic sector consumption was 18%, commercial 6%, industrial 39.6% (with low and medium tension industries 8.4% and high tension industries 31.2%), agriculture 29.8%, traction 2.3%, public water works 2%, public water works 0.8% and miscellaneous 1.5% respectively. Also, the electricity tariff structure is different for different consumer categories. In view of this, the analysis in the study would be restricted to five sectors viz., domestic, commercial, industries (low & medium voltages together and high voltages) and agriculture.

Electricity demand by various consumer categories is characterized by constrained supply of electricity. Over the years the demand-supply gap of electricity has widened in all the regions except the western region. This suggests that the unfulfilled demand of electricity expressed as power shortages by the State Electricity Boards has grown over the years. Though the State Electricity Boards provide estimates of power shortages since 1984/85 at an aggregate level, no data exists on sectoral power shortages. Without the shortages figure available for different consumer categories, it is difficult to estimate the actual electricity demand in each category. In absence of such information the study would consider electricity sales to different consumer categories as the level of electricity consumption (or the

unfulfilled demand). Perhaps the major reason for such growing shortages is insufficient funds. However, since the mid-sixties, outlay for the power sector has been rather high at 16-19% of the total public sector outlay and the scope for increasing its share is, therefore, limited. Consequently, the power industry has little choice but to enhance its internal resource generation.

One of the ways of generating such resources is by restructuring tariffs in line with the costs of power generation and supply. In fact, energy prices in India are administered, with the goal of pursuing certain social objectives. They do not, in general, reflect costs. For instance, electricity tariffs are lower than supply costs -- this is particularly true of electricity sales to farmers, or whom the tariffs are the lowest whereas the costs borne by power utilities for supply of power may well be the highest. These low tariffs have contributed significantly to the losses in state electric utilities.

To estimate the income and price elasticity of electricity consumption by different consumer categories, equations of the following form will be used:[37]

$$\ln E^*_{t,s} = a + b \ln Y_t + c_0 \ln P_{t,s} + c_1 \ln P_{t-1,s} + c_2 \ln P_{t-2,s} + \ldots + c_m \ln P_{t-m,s} \quad (3)$$

where $E^*_{t,s}$ and $P_{t,s}$ are respectively per capita total electricity consumption in sector s and the corresponding sectors electricity tariff (including differentiation by customer size (Low & Medium Tension and High Tension industries) in year t. Y_t denotes the per capita GDP in year t. Subscript t-m denotes m-year lagged value. a is the intercept and b is the income elasticity with respect to the sth consumer category. While, c_0 is the short-run price elasticity and Σc_i is the long-run price elasticity with respect to the consumer category s. The parameters of the regression equations can be estimated using the ordinary least squares fit.

Income and price elasticities will be compared under different lag assumptions. To start with, a simple static model with no lagged effects in which $c_1 = c_2 = c_3 = \ldots = c_m = 0$. Next, the long run price elasticities (i.e., a, b, c_0, c_1, ..., c_m) will be estimated by considering an appropriate lagged effect (say assuming a maximum lag of 5-years).

Sectorwise electricity tariff data available since 1985 has been compiled using the Annual Report on the working of State Electricity Boards and Electricity Departments.[38] The corresponding data for the sectorwise per capita electricity consumption is compiled from the Central Electricity documents.[39]

Apart from electricity tariff, electricity consumption in different consumer categories is expected to be heavily influenced by a number of other variables. These would include

industrial structures (with regards to the GDP share in the case of electricity consumption in the LT and HT industries), the extent of urbanization, etc. To understand how elastic are these variables relating to electricity consumption, the study proposes to use similar equations described above. Time series data on each of these variables have been compiled from different sources for the last 25 years.

5. Workplan

Activity	Milestone (week number with effect from 14.11.1996)										
	1	2	3	4	5	6	7	8	9	10	11
1. Literature review	▨	▨	▨								
2. Data collection and compilation	▨	▨	▨	▨							
3. Finalizing the framework for analysis			▨								
4. Submission of the interim report			▨								
5. Data analysis				▨	▨	▨	▨	▨			
6. Results and discussions							▨	▨	▨		
7. Submission of the draft final report									▨		
8. Submission of the final report											▨

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